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RELATIONSHIP OF BIOLOGICAL DIVERSITY TO SCENIC QUALITY

by
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Relationship of Biological Diversity to Scenic Quality

Final Report
Cooperative Agreement No. 28-CO-548

between

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and
Rocky Mountain Forest and Range Experiment Station

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21 July 1993

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Introduction

Application of psychophysical methods to understand human perception of forest scenic beauty has produced an impressive array of information for selected vegetation types. Studies performed in several countries indicate what amounts and combinations of overstory, understory, and downed wood are preferred. Within the overstory, studies have differentiated among trees of different species and size classes, indicating which species and what size classes of those species are preferred. Yet, no studies have determined to what extent scenic preferences are related to biological diversity.

Evolutionary theories of landscape preference, which maintain that human landscape preference developed over time in response to the ability of environments to support life and enhance survival, suggest that biological diversity may play a role in or be related to scenic quality. The relationship of biological diversity to scenic quality is of current and practical interest because of the increasing realization of the value of biological diversity and the willingness of land managers to consider biological diversity in developing forest management plans. These perspectives naturally raise questions such as: To what extent and in what conditions is scenic quality compatible with biological diversity; and do forest users naturally prefer forests of high levels of biological diversity, or will moves to protect or enhance biological diversity threaten scenic quality? This study is a step toward answering some of these questions for southwestern ponderosa pine ecosystems. The primary goal of the study was to develop an initial understanding of the relationship of biological diversity to human preference for scenic quality in these forests.

Biological diversity can be approached at various spatial levels, from the forest site level, to the stand level, to the landscape level. Psychophysical studies of near-view forest scenic beauty have typically assessed scenic beauty at the site or stand level. Scenic quality was assessed for individual points in the forest (usually represented by 4 scenes), or in some cases relatively homogeneous forest stands (represented by up to 60 scenes), and described in terms of biological and physical site features. In some cases, the biological and physical information is sufficient to allow other types of analysis, including evaluations of biological diversity. Existing biophysical data files for forest areas where site-level or stand-level psychophysical scenic beauty models have been developed, such at those for the Woods and Bar-M watersheds, could thus be accessed to evaluate biological diversity, and the resulting measure could be compared with previously developed measures of near-view scenic beauty.

Scenic beauty at the landscape level could be assessed from two very different perspectives. First, an entire landscape may be captured in one expansive vista view. Vista scenes focus on distant patterns of vegetation; detailed stand characteristics are not distinct. Second, a landscape can be represented by a set of near-view scenes, each depicting detailed stand characteristics at a given point in the landscape, such as those that would be viewed in a hike through the landscape. Landscape scenic quality from this perspective is a function of the scenic beauty of each scene and of the mixture of scenes that make up the landscape.

The specific objectives of this study are as follows:

1. Measure biological diversity for points and stands for which a measure of relative scenic beauty is available and characterize the relationship of biological diversity to scenic beauty.

2. Measure biological diversity for forest landscapes characterized by a mix of forest points or stands and explore the relationship of biological diversity to near-view scenic beauty at the landscape level.

3. Develop testable hypotheses for further study about the relationship of biological diversity to scenic beauty, suggest improved empirical methods for use in future studies, and develop a research proposal incorporating these hypotheses and procedures.

Biological Diversity and Scenic Beauty at the Point and Stand Level

The first objective was accomplished by calculating the Shannon-Wiener diversity index (H') of points sampled in the multiresource inventory (MRI) of the Beaver Creek Watershed Study (see Brown and Daniel 1984 for a description of the MRI). The relationship between scenic beauty estimates (SBE) and various measures of H' was then explored.

The Shannon-Wiener diversity index is the most widely used of the numerous diversity indexes (Pielou 1977, Magurran 1988). Although most applications of the index are at the species level, this index has also been used for other taxonomic levels as well as for structural categories (Elton and Miller 1954, MacArthur and MacArthur 1961, Harper 1977, Southwood et al. 1979, Kirby et al. 1986).

Shannon-Wiener diversity is calculated as:

$$H' = -\Sigma p_i \ln p_i$$

where

H' = the Shannon-Wiener diversity index
p_i = the proportion of individuals in the i^{th} species (or category, e.g., tree diameter class).

Shannon-Wiener diversity indexes were calculated for each point as follows:

1. HTREE--This measure of H' was used to estimate the diversity of trees on a plot. For this index, there were a maximum of 18 categories (analogous to species in the H' equation). These categories consisted of three taxonomic classes (ponderosa pine, Gambel oak, and other) times six size classes (CLASS 1 [$\leq$ 1 foot tall + 1-4.5 feet tall] CLASS 2 [4.5 feet tall - 4.9 inches dbh], CLASS 3 [5-8.9 inches dbh + 9-11.9 inches dbh], CLASS 4 [12-15.9 inches dbh], CLASS 5 [16-19.9 inches dbh + 20-23.9] inches dbh, CLASS 6 [24-27.9 inches dbh + $\geq$ 28 inches dbh]).

2. HTOTFOL--This index was used to estimate diversity of foliage. The categories were ponderosa pine foliage, Gambel oak foliage, grass foliage, forb foliage and shrub foliage. Foliage biomass for ponderosa pine and Gambel oak was calculated using allometric regression equations.

Point level comparison

Data were available to compute HTOTFOL, HTREE, and SBE for 1320 MRI points. Table 1 summarizes the three variables.

Table 1. Descriptive Statistics

	SBE	HTOTFOL	HTREE
mean	17.81	0.32	0.84
standard deviation	31.80	0.31	0.37
skewness	0.07	0.25	-0.23
minimum	-83.75	0.0	0.0
maximum	122.0	1.25	1.82

Histograms of the three variables are presented in Figures 1-3. The correlation matrix across these points is presented in Table 2.

Table 2. Point-level Pearson Correlation Matrix (n=1320)

	SBE	HTOTFOL
HTOTFOL	-0.034	
HTREE	-0.159**	0.178**

** = significant at 0.001

Because univariate distributions (see skewness coefficients in Table 1 and Figures 1-3) indicate that HTREE and HTOTFOL are not normally distributed, Spearman correlation coefficients were also computed. However, these coefficients are nearly identical to the Pearson correlation coefficients listed in Table 2.

The correlation coefficient of SBE with HTOTFOL is not significant. However, the coefficient of SBE with HTREE is highly significant, indicating that SBE declines as biological diversity of these tree categories increases.

Stand-level comparison

Brown and Daniel (1986) found that stand boundaries in ponderosa pine tended to group points of like scenic beauty. For a subset of MRI stands that they evaluated, the stand boundary accounted for 44% of the total variation in SBE across the points. This raises the possibility that stand average measures of SBE and the biological diversity variables may indicate a greater relationship than found at the point level.

The 1320 points are found in 82 stands. Each stand was represented by a minimum of 13 points. Analyses of variance indicated that the stand boundaries also tended to group areas of like scenic beauty and like biological diversity among the 82 stands (each analysis was highly significant, with $p < .0001$). Stand boundaries accounted for 48% of the variance in SBE among the points, for 22% of the variance in HTREE, and for 39% of the variance in HTOTFOL.

However, averaging within stands did not radically increase the correlations among the three variables, as indicated in Table 3.

Table 3. Stand-level Pearson Correlation Matrix
(n=82)

	SBE	HTOTFOL
HTOTFOL	-0.134	
HTREE	-0.318*	0.390**

* = significant at 0.01
** = significant at 0.001

Further, regression of SBE on the two biological diversity indices produces an R^2 of 0.10, with only HTREE being significant (at the 0.05 level or better).

Biological Diversity and Scenic Beauty at the Landscape Level

The second objective was accomplished by calculating five widely used diversity measures for ten simulated hikes through a ponderosa pine forest. In calculating diversity, substand type was used to represent broad structural changes. Three substand types were used. Yellow pine substands were old (200-500 yrs) ponderosa pine with yellow bark. They were generally 37.5-105 cm dbh. Pole substands were intermediate in age (74-116 yrs) and diameter (10-37.4 cm dbh). They had black to grey bark. Sapling substands were youngest (57-73 yrs old) and had the smallest diameters (0-9.9 cm dbh). Their bark color was black to grey also.

The simulated hikes were depicted by combinations of 9 photos each representing one of these three stand types. The combinations are listed in Table 4.

Scenic Beauty Index

The procedure for estimating SBEs for the hikes is described in the final report of cooperative agreement 28-C0-551 between the Rocky Mountain Station and T. C. Daniel of the University of Arizona. SBEs were obtained from both prints and slides. Both sets of SBEs for the 10 simulated hikes are listed in Table 4.

Diversity Indexes

Magurran (1988) and Pielou (1977) have presented excellent reviews of various diversity indexes and how to calculate them. As previously stated, most studies have examined diversity at the species level. However, these same indexes can be used to measure structural and habitat diversity at different levels of aggregation (Elton and Miller 1954, MacArthur and MacArthur 1961, Harper 1977, Southwood et al. 1979, and Kirby et al. 1986). For this research, each substand type is treated as a taxonomic entity (category).

Diversity indexes were chosen to represent a range of factors thought to be important by ecologists. **Interspersion** (Baxter and Wolfe 1972) is a measure of the degree to which different habitats are intermingled. Of the five measures chosen for this study, it is the only one sensitive to the order in which the substands are encountered. Since all of the hikes had the same number of scenes, the simplest measure of **richness** can be easily calculated as the number of substand types represented in each hike. The **Shannon-Wiener diversity index**, perhaps the most widely used diversity measure, is strongly influenced by richness, but also includes evenness, the degree to which the entities are distributed evenly among categories. Evenness is most widely calculated using the **Shannon evenness index**. Dominance is most commonly estimated by **Simpson's index**.

Table 4. Ponderosa pine substand (Y=yellow pine, P=pole, S=sapling) sequence for simulated hikes. Diversity indexes are: I=interspersion, R=species richness, H'=Shannon's diversity, E=Shannon's evenness, and D^{-1}=Simpson's dominance.

Hike #	Composition			Sequence									Diversity Indexes					Scenic Quality	
#	Y	P	S	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	I	R	H'	E	D^{-1}	Print	Photo
1	9	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	0	1	0	0	1.000	71.93	65.92
2	8	1	0	Y	Y	Y	Y	P	Y	Y	Y	Y	2	2	.349	.504	1.286	45.60	50.62
3	8	0	1	Y	Y	Y	Y	S	Y	Y	Y	Y	2	2	.349	.504	1.286	60.49	59.31
4	7	1	1	Y	Y	P	Y	Y	Y	S	Y	Y	4	3	.684	.623	1.714	69.63	60.54
5	7	2	0	Y	Y	P	Y	Y	Y	P	Y	Y	4	2	.530	.765	1.636	45.26	50.23
6	7	0	2	Y	Y	S	Y	Y	Y	S	Y	Y	4	2	.530	.765	1.636	65.04	65.46
7	5	2	2	Y	P	Y	S	Y	P	Y	S	Y	8	3	.995	.906	3.000	62.36	58.92
8	3	3	3	Y	P	S	Y	P	S	Y	P	S	8	3	1.099	1.000	4.000	47.94	47.62
9	1	7	1	P	P*	Y	P	P	P	S	P	P	4	3	.684	.623	1.714	45.79	31.31
10	0	9	0	P	P	P	P	P	P	P	P	P	0	1	0	0	1.000	23.22	15.46

1. **Interspersion (Baxter and Wolfe 1972)**. The concept of habitat interspersion as a measure of landscape diversity was proposed by Leopold (1931). Interspersion is calculated by summing the number of habitat changes along transects through a given landscape. If the transect is all of one habitat category then I=0 (i.e., there were no changes along the transect). If the transect began in category Y, then entered P, then Y, I=2 (two changes, Y to P, then P to Y), etc.

2. **Richness**. Richness calculation is very simple if all the constituent entities are known. Complications arise when sample unit size (area) varies or when entities are sampled instead of censused. Since our simulated walks consist of a census, richness is merely the sum of the categories of substands included. Thus in our case if only 1 substand is included, then R=1. If 2, then R=2, and if 3, then R=3.

3. **Shannon-Wiener diversity index (Wiener 1948, Shannon and Weaver 1963).** This is the most widely used diversity index. It is based on the rationale that the diversity in an ecological system is analogous to the information contained in a code or message (the formula is actually borrowed from information theory). The index is calculated as:

$$H' = -\Sigma p_i \ln p_i$$

where

H' = the Shannon-Wiener diversity index
p_i = the proportion of individuals in the i^{th} species.

4. **Shannon's evenness (Shannon and Weaver 1963)**. Shannon's evenness index is a measure of how evenly the number of individuals are distributed among categories. For this measure, the maximum diversity would occur when all categories are equally abundant (E=1.0) and the minimum (E=0) would occur when all individuals are in one category. This index is calculated as:

$$E = H'/\ln S$$

where

H' = the Shannon-Wiener diversity index
S = the number of categories (typically species).

5. **Simpson's dominance index (Simpson 1949)**. This index is weighted toward the abundances of individuals in the most dominant categories. Simpson's dominance index is calculated as:

$$D=\Sigma\left(\frac{n_i(n_i-1)}{N(N-1)}\right)$$

where

n_i = the number of individuals in the i^{th} category
N = the total number of individuals

Simpson's index is usually reported as D^{-1} so that as dominance increases, diversity decreases.

Results

Diversity measures for these five diversity indexes are listed in Table 4 for the ten hikes. All five indexes show that diversity is greatest for hike 8, which consists of an equal number (i.e., 3) of the three kinds of substands. As seen in Table 5, the two scenic beauty variables are highly correlated, and the five diversity indices are highly correlated, but there is little relation between scenic beauty and biological diversity.

Table 5. Landscape-level Pearson Correlation Coefficients
(n = 10)

	SBE(print)	SBE(slide)	I	R	H'	E
SBE(slide)	0.921**					
I	0.169	0.205				
R	0.219	0.140	0.846*			
H	0.177	0.182	0.981**	0.927**		
E	0.187	0.297	0.922**	0.835*	0.931**	
D^{-1}	0.055	0.096	0.925**	0.707	0.896**	0.776*

* = significant at 0.01 ** = significant at 0.001

Again, as was the case for site-level scenic beauty, there is no strong relationship between these measures of diversity and scenic beauty.

Conclusions and Testable Hypotheses for Future Research

This study has failed to demonstrate any strong relationship between scenic beauty and the various measures of diversity calculated from an existing database. Whether other categories (analagous to species) or other measures of esthetics would yield the same results is uncertain. A necessary step before pursuing further research regarding relationships between scenic beauty and diversity is the definition of all categories of forest structure which are perceived as contributing to scenic beauty. These additional categories (perhaps including groups such as yellow flowering plants, dark green foliage, etc.) might contribute substantially to the discovery of relationships between scenic beauty and diversity.

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Figure 1. Histogram of SBE at 1320 MRI Points

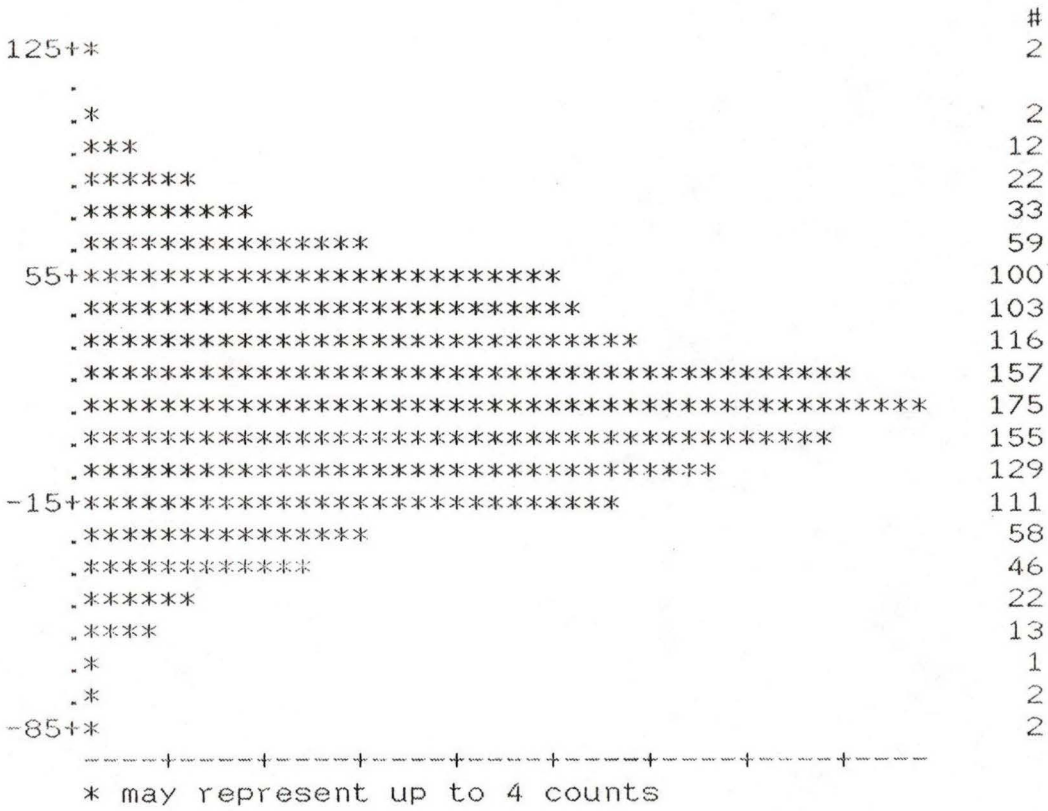

Figure 2. Histogram of HTOTFOL at 1320 MRI Points

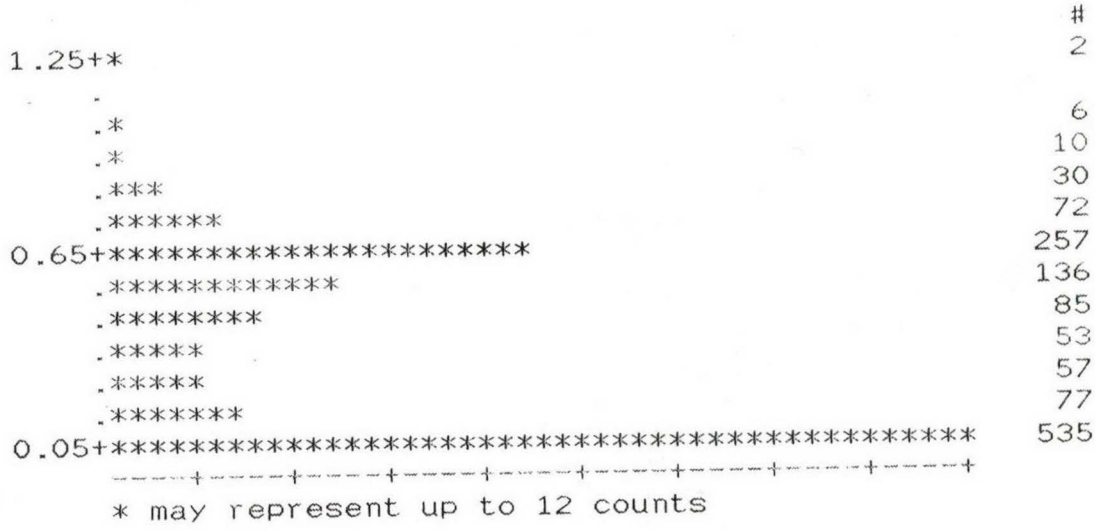

Figure 3. Histogram of HTREE at 1320 MRI Points